Reciprocating Engines in Distributed Energy and CHP Applications

3rd Annual National CHP Roadmap Workshop
DER & CHP in Federal Facilities

Boston, October 23 - 25, 2002

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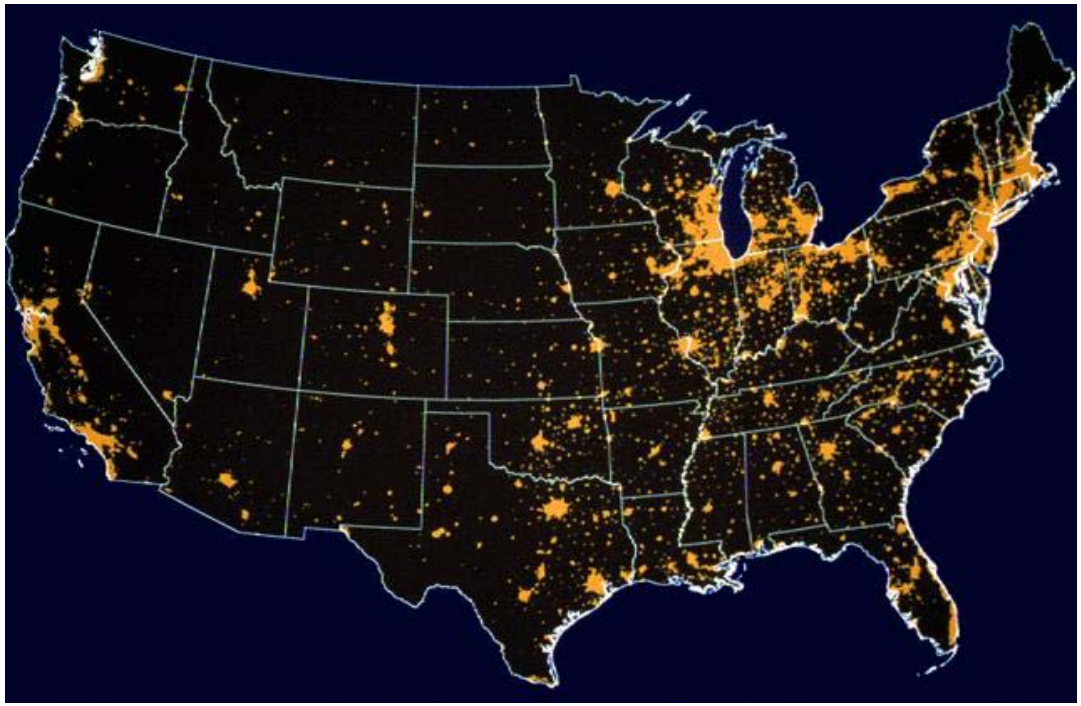
Let's Start with a Quote

"Reciprocating gas engines are the fastest selling, least expensive distributed generation technology in the world today."



Source: Office of Power Technologies
www.eren.doe.gov/power

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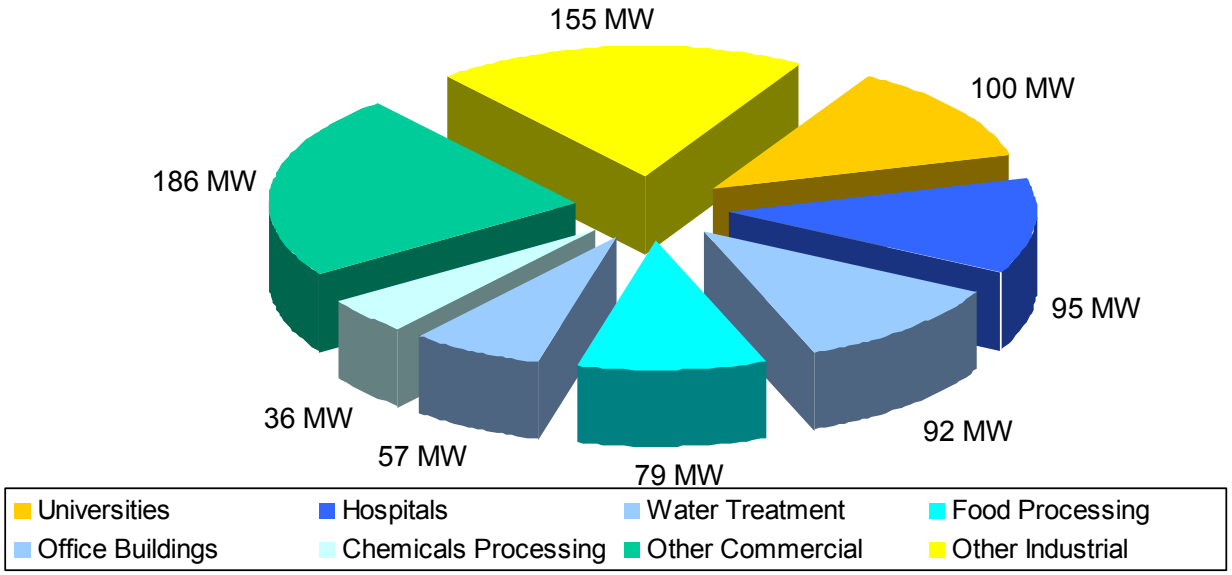
Existing Reciprocating Engines in CHP

- Reciprocating engine technology is established and proven
- Represents significant portion of installed base, particularly under 20MW

801MW at 1,055 sites



Source: PA Consulting, Energy Nexus Group

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Why Use Reciprocating Engines

- Simple Cycle Efficiency
- Thermal Efficiency
- kW(e) - kW(th)
- Reliability
- Emissions
- Installed costs
- Running costs
- What you see is what you get

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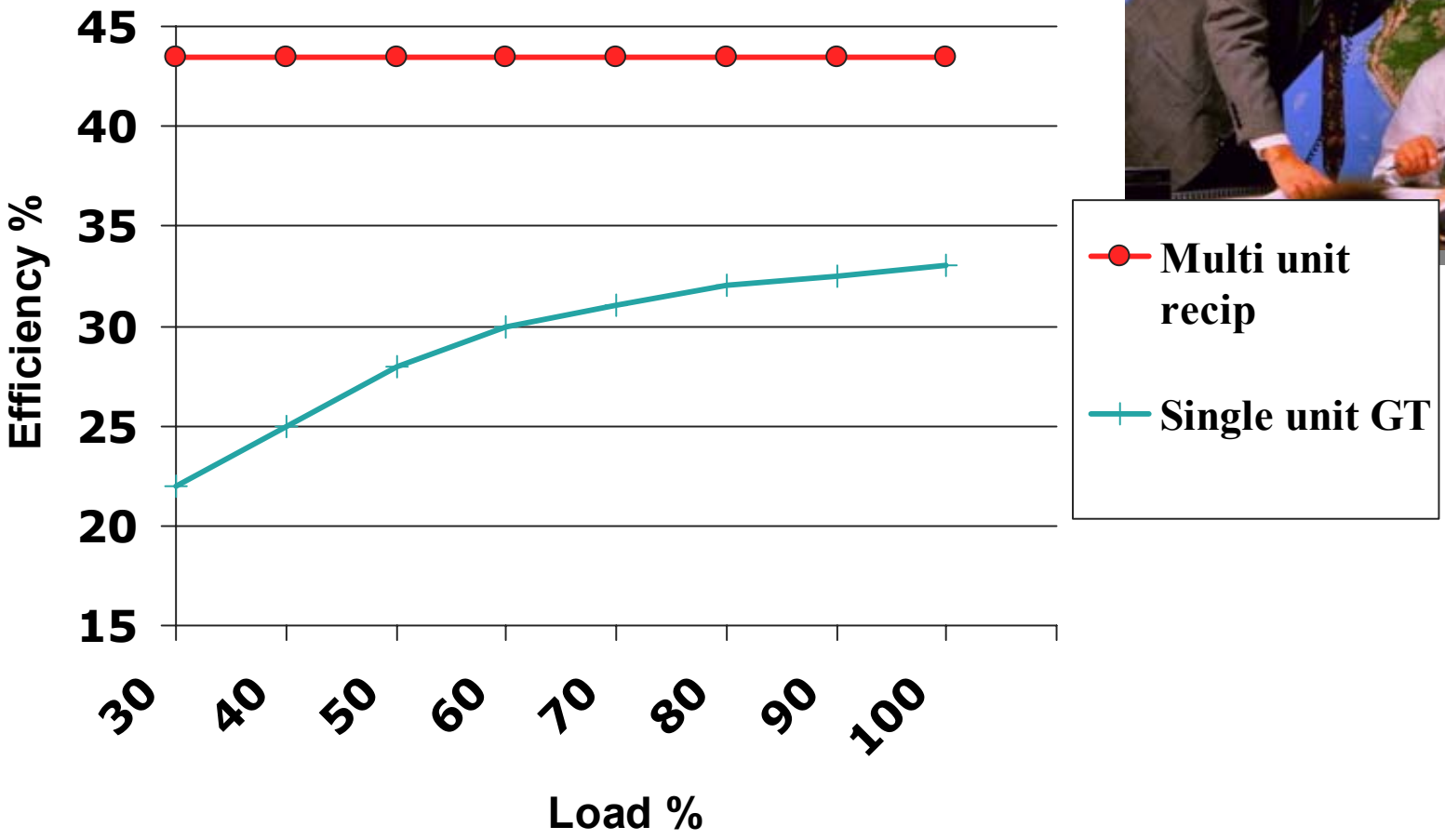
Simple Cycle Efficiency

- High electrical efficiency 35% - 42%
- Multiple units = Operational Flexibility



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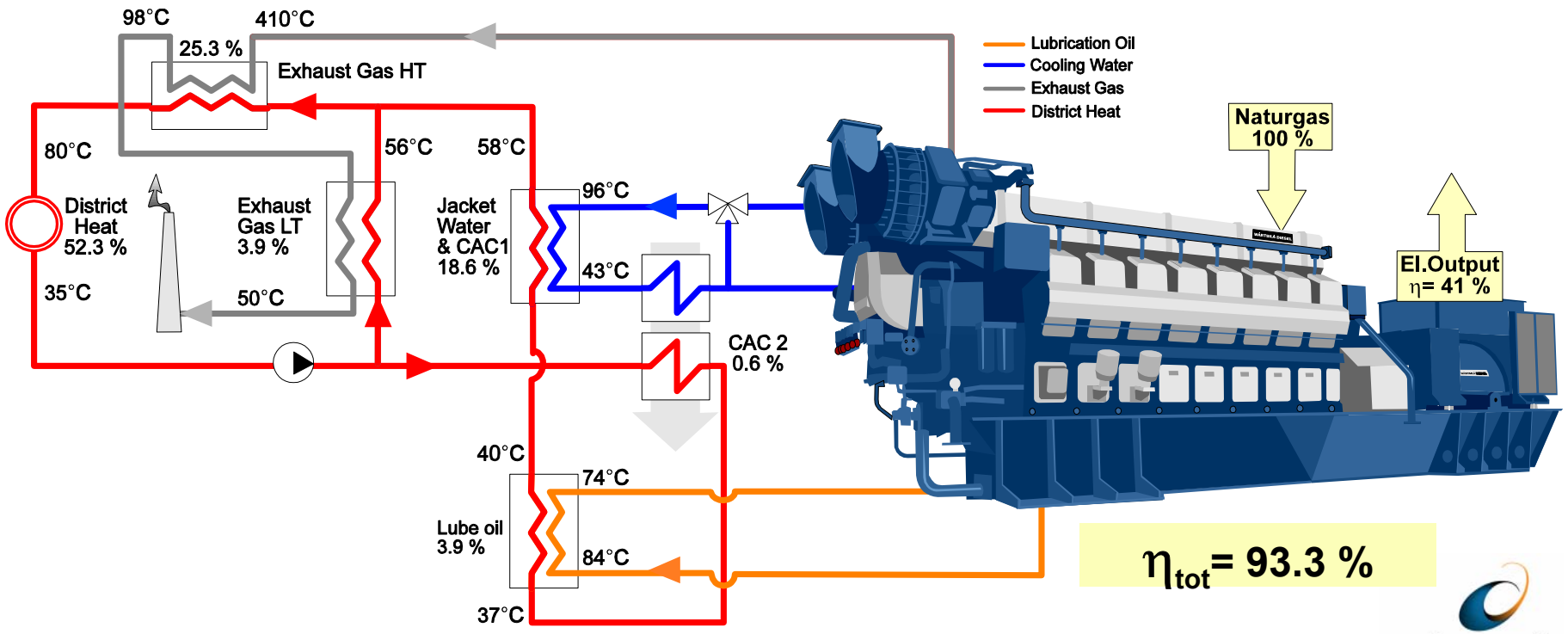
Thermal Efficiency

90% overall efficiency achievable
75%+ common
Excellent for low grade heat
Relatively inexpensive heat recovery process
Steam and hot / cold water available



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kW(e) - kW(th)

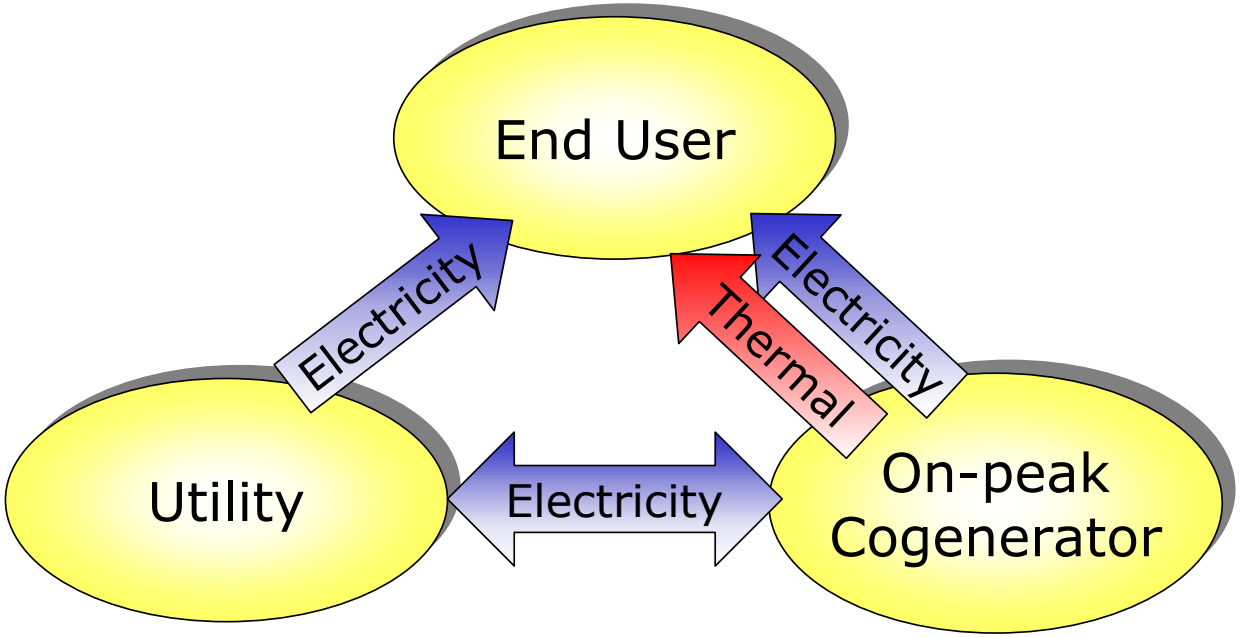
True captive power requires optimum balance of thermal and electrical energy

BUT

Economic solution may be optimized by

- Matching thermal load and installing excess electrical capacity
- Utilizing existing thermal equipment

Reciprocating Engines offer greatest flexibility



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Reliability of Natural Gas Fueled Co-Gen Systems

- Utilizing multiple units greatly enhances system reliability and availability
- N+1(or 2) Reliability cost effective with reciprocating engines

	Reciprocating Engine			Gas Turbine Engine			Electric Utilitiy (a)
Operational Reliability Measure (b)	Group 1 60 kW	Group 2 80-800 kW	Group 3 > 800 kW	Group 4 1-5 MW	Group 5 5-25 MW	Group 6 >25 MW	1986-1990
Availability Factor, %	95.8	94.5	91.2	92.7	90.0	93.3	85.9
Forced Outage Rate, %	5.9	4.7	6.1	4.8	6.5	2.1	24.7
Scheduled Outage Factor, %	0.2	2.0	3.5	3.0	4.1	4.8	9.9
Service Factor, %	63.0	68.8	80.8	85.3	85.2	95.5	40.0

(a) Average values are weighted by unit-years for fossil-boiler, nuclear, jet engine, gas turbine, and combined-cycle units from data reported in Generating Unit Statistics, 1986-1990, North American Electric reliability Council/Generating Availability Data Systems.

(b) All figures are average. Operational reliability measures are consistent with American National Standards Institute/Institute of Electrical Engineers' Standard 762.

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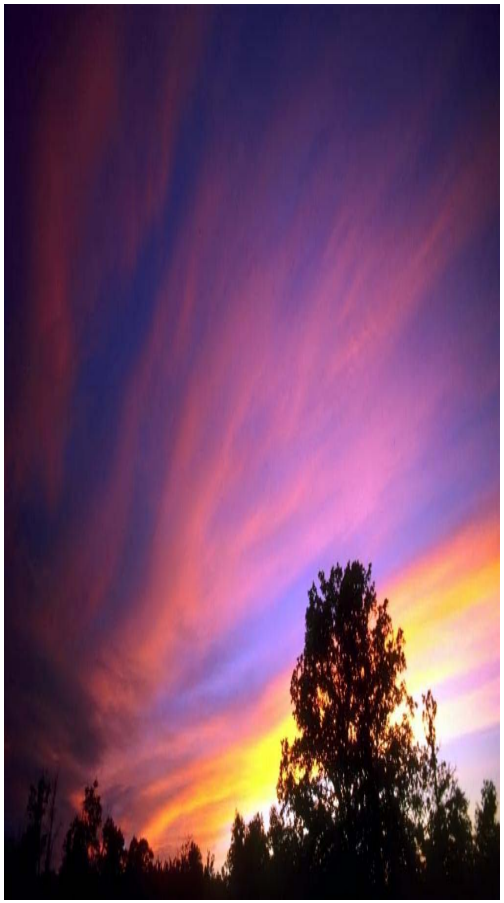
Emissions

Stochiametric burn engines w/ 3 way catalyst or lean burn engines w/ SCR are as clean as any technology.



Gas Engine Emission Charecteristics

	Emissions Untreated*	Emissions Treated	
	lb/MWhr	lb/MWhr	PPM_v *1
NOx (as N_2)	1.480	0.222	6
CO	6.500	0.650	33
VOC	1.180	0.295	21
Particulates	0.176	0.176	NA

* Source Technology Charecterization: Reciprocating Engines Energy Nexus Group

*1 at 15% O_2 dry

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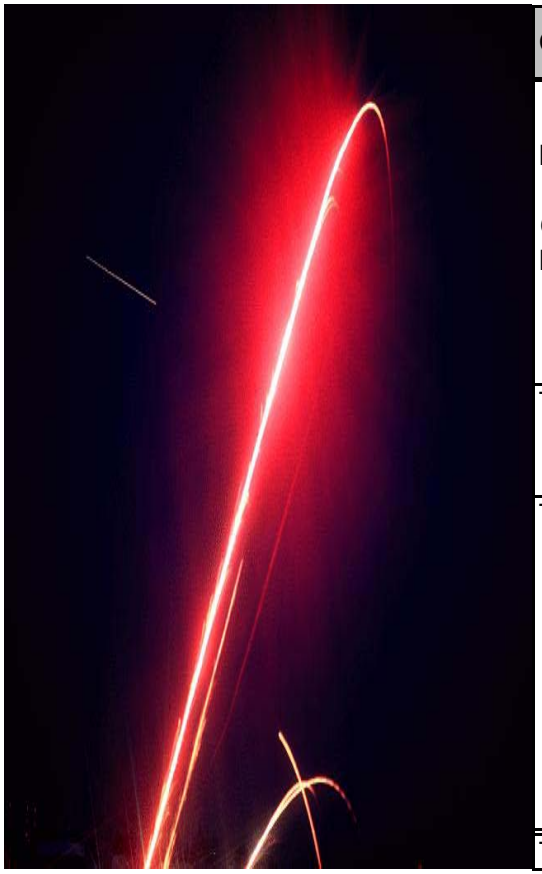
Installed Costs

- $1500/kW installed cost on small systems
- $750/kW installed on large systems
- Rapid project schedules



Cost Component	System 1	System 2	System 3	System 4	System 5
Nominal Capacity (kW)	100	300	800	3,000	5,000
Costs ($/kW)					
Equipment					
Gen Set Package	$260	$230	$269	$400	$450
Heat Recovery	$205	$179	$89	$65	$40
Interconnect/Electrical	$260	$90	$40	$22	$12
Total Equipment	$725	$499	$398	$487	$502
Labor/Materials	$359	$400	$379	$216	$200
Total Process Capital	$1,084	$899	$777	$703	$702
Project and Construction Management	$235	$158	$121	$95	$95
Engineering and Fees	$129	$81	$45	$41	$41
Project Contingency	$43	$34	$28	$25	$25
Project Financing (interest during construction)	$24	$25	$31	$55	$55
Total Plant Cost ($/kW)	$1,515	$1,197	$1,002	$919	$919

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Source: Energy Nexus Group

Running Costs

- Popular mis-conception that maintenance costs are high
- No equivalent operating hours or maintenance factors
- Even small high speed engines very durable
- Enormous installed base

Typical Natural Gas Engine Maintenance Costs

System Size kW	100kW	300kW	800kW	3,000kW	5,000kW
Maintenance Costs[*1]					
Variable (service contract) $/kWhr	0.017	0.012	0.009	0.009	0.009
Variable (consumables $/kWhr	0.00015	0.00015	0.00015	0.00015	0.00015
Fixed, $/kWyr	10	5	4	1.5	1.1
Total O&M Costs $/MWhr	1.84	1.28	0.97	0.93	0.93
Typical time to overhaul (khours)	30-36	30 -36	30 - 36	48 - 60	40 - 72

[*1]Maintenance costs are based on 8000 operating hours per year

Source: SFA Pacific, Inc Energy Nexus Group

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What You See is What You Get

- Full output up to 122°F
- Full output up to 5000 ft
- Guaranteed performance
- Guaranteed availability
- Guaranteed costs
- Negligible performance degradation

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Ideal Applications for Reciprocating Engines



Thermal applications

- Hot Water
- Steam (up to 125 psi)
- Chilled water

Project criteria

- 100kW - 50MW
- Low thermal - electrical energy ratio
- Hot high and dry
- Varying load
- High reliability need
- Flexible dispatch

Installation types

- Hospitals
- Universities
- Municipalities
- Light Industrials
- Office/Corporate HQ
- Prisons
- Laundries
- Hotel/Resorts
- Casinos
- Data Centers

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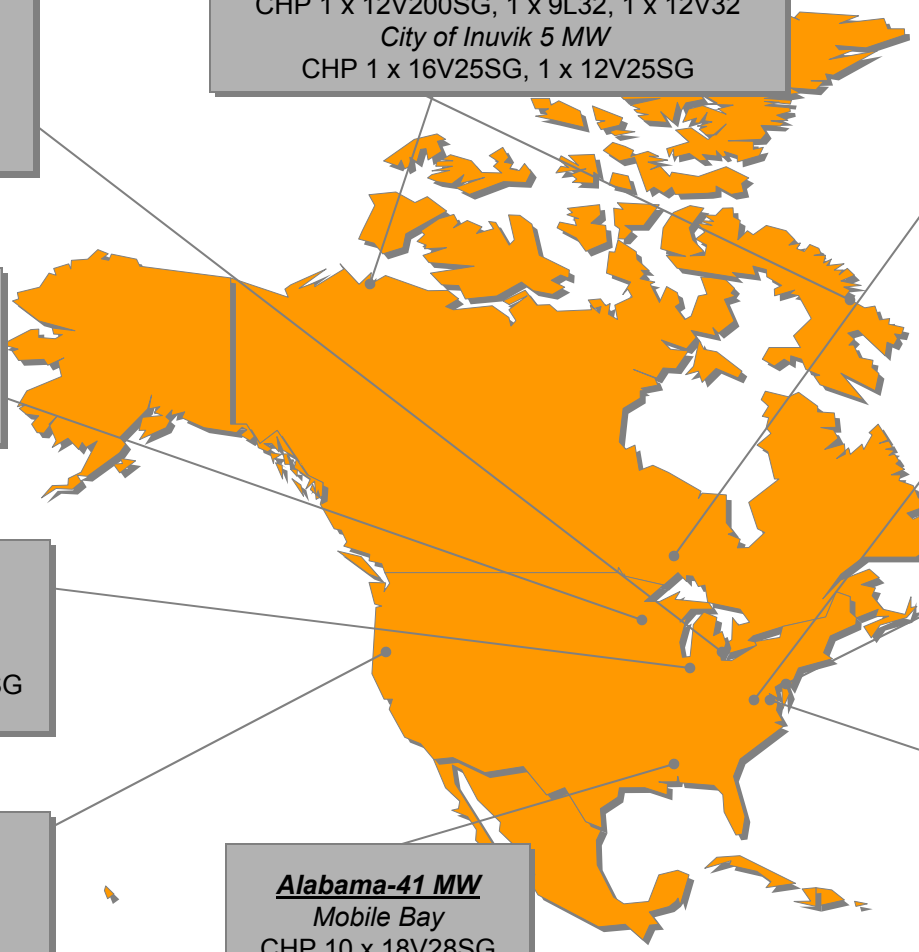
Wärtsilä CHP References in North America



North West Territories-14 MW
City of Iqaluit 9 MW
CHP 1 x 12V200SG, 1 x 9L32, 1 x 12V32
City of Inuvik 5 MW
CHP 1 x 16V25SG, 1 x 12V25SG

Ontario-5 MW
City of Cornwall
CHP
2 x 16V25SG

Michigan- 17 MW
Detroit Airport
CHP
3 x 18V34SG

Maryland-25 MW
Federal Research Center
CHP
5 x 18V32DF

Minnesota-14 MW
Northern States Power
Standby
2 x (2 x UD45V16)

New Jersey -9 MW
Mannington
CHP
3 x 18V220SG

Illinois-25 MW
University of Illinois
CHP
2 x 18V28SG, 3 x 18V34SG

Maryland-25 MW
Sweetheart Cup 11 MW
CHP 2 x 18V34SG
BG&E 14 MW
Standby 2 x (2 x UD45V16)

Oregon-14 MW
Wah Chang
CHP
5 x 18V220SG

Alabama-41 MW
Mobile Bay
CHP 10 x 18V28SG

170 MW Total Capacity

Revised 4/2002

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